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Testing for Energy Recovery Ventilators and Energy Saving Analysis with Air-Conditioning Systems

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Abstract

Energy recovery ventilators (ERVs) transfer energy between the air exhausted from building and the outdoor supply air to reduce the energy consumption associated with the conditioning of ventilation air. Higher ventilation rates improve the IAQ by diluting pollutants such as airborne particles and VOC. On the other hand, studies have shown that higher ventilation rates increase the building energy consumption in a majority of cases, especially during the hot summer season. Therefore, more energy is required to provide the space with more outdoor ventilation air and consequently better IAQ. The ERVs is important equipment for indoor air conditioning. The study results show that the ERVs can be energy saving and reduce indoor air pollution of modern buildings, improve indoor work and living environment. Testing for energy recovery ventilators and energy saving analysis with air-conditioning systems, the result can provide basic principle and referenced data for product improvement and air-conditioning system design.

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Keywords: Energy recovery ventilators; Energy consumption; Climatic condition; Indoor environment

1. Introduction

The rapid development of the economy improve continuously people's quality of life, and environmental quality requirements have also increased, so it is imperative that attaching great importance to energy recycling. The total energy consumption in China continues to grow. As 2002, total energy consumption in China has grown from 987

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million tons in 1990 increased to 1.48 billion tons of standard coal, accounting for 9.78% of the total world energy consumption [1]. Meanwhile, the average utilization rate is only about 30% in China, and per dollar of GDP energy consumption is three times the world average, is twice times the average for all developing countries [2]. The energy consumption of unit building area in China is 2-3 times higher than in developed countries with the same climate conditions, and showed a growing trend [3]. In China's energy consumption, building energy consumption up to 30% and air conditioning energy consumption accounted for more than 60% of building energy consumption, thus energy saving and economics of air conditioning have paid more and more attention to relevant institutions and persons [4]. In reality, the room of air conditioning heat is emitted into the atmosphere, which causes thermal pollution in the city and makes heat energy not be able to be taken full advantage of [5]. In order to improve the IAQ by diluting pollutants and reduce the energy consumption of air-conditioning system, this paper has a detailed analysis to the energy recovery ventilators (ERVs).

2. Composition and working principle of fresh air ventilator

2.1. Classification of fresh air ventilator

Heat recovery equipment according to the operating principle can be divided into rotary type, plate (skip) type, heat pipe type and intermediate media type; according to the different amount of heat recovery can be divided into total heat recovery unit and sensible heat recovery unit [6]. Total heat exchanger (also known as enthalpy exchangers) is an exhaust and fresh air of air-conditioning system for recovery of heat and humidity between devices [7], and sensible heat recovery unit is recovery heat only.

2.2. The principle of fresh air ventilator

To this experiment of ventilation in summer, for example, 26 ℃ dirty indoor air from exhaust air inlet into the exhaust air outlet to the outside, forming a warming currents; while 33℃ fresh outdoor air from the outdoor air inlet into the export to interior, forming a drop air stream. Two air flow along the process of reverse flow on both sides of the heat exchanger, due to exhaust temperature nearly 26 ℃, air temperature close to 33 ℃, the two air make heat exchange by heat plate at 7 ℃ temperature difference, lower air temperatures, making passes cooling capacity that will be discharged to the outdoor to the fresh air, so as to achieve the purpose of heat recovery. The principle shows in figure 1.

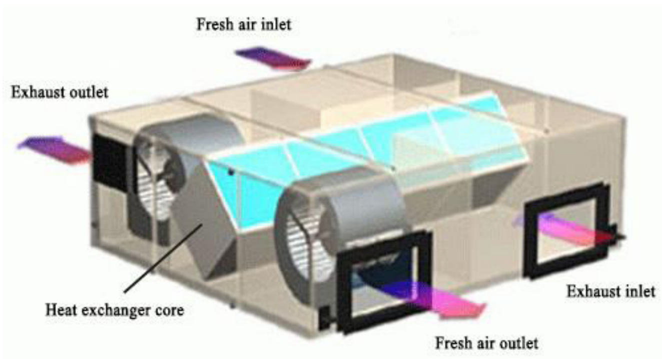

Fig. 1. Schematic diagram of fresh air ventilator

Fresh air ventilator to the exhaust air of air-conditioning system is increasing fresh air while saving energy, improving indoor air quality [8]; Although the use of exhaust heat recovery system will also increase a certain amount of fan energy consumption, the energy saved by recycling the system itself is much larger than the energy consumption of this part [9].

3. Efficiency calculation of fresh air ventilator

There are two fresh air ventilators efficiency in calculating methods: The wind tube method and the two chamber method[10]. This paper adopts two-Chamber method, its principle as Figure 2. The dry-bulb temperature and relative humidity of outdoor air (wj), supply air (wc) and exhaust air (nj) under the two kinds of wind velocity were measured respectively. And the exhaust air temperature default to the design temperature of indoor air. Other measurements are shown in Table1 and Table 2.

According to the standards, the formula is given heat transfer efficiency of fresh air ventilator

$$\eta_t = (t_{wj} - t_{wc}) \div (t_{wj} - t_{nj}) \times 100\% \tag{1}$$

Where η_t is sensible heat exchange efficiency; t_{wj} is dry-bulb temperature of Outdoor air; t_{wc} is dry-bulb temperature of indoor supply air; t_{nj} is dry-bulb temperature of indoor air.

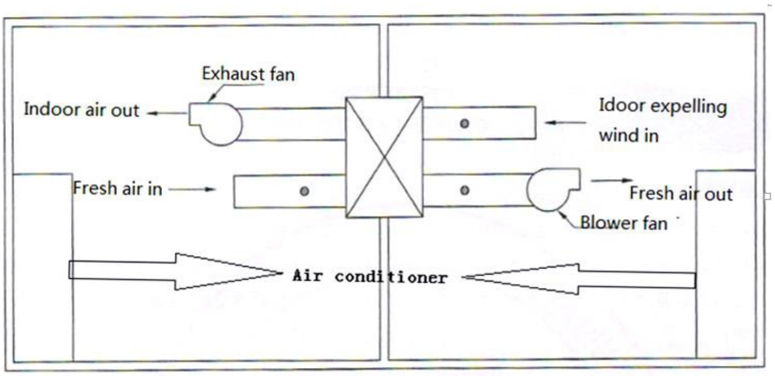

Fig. 2. The principle diagram of the two chamber method test.

Table 1. Summer air ventilator measurement data in Xiamen (interior design temperature 26 ℃, different outdoor temperature data)

Mean wind velocity (m/s)	Outdoor temperature (℃)	The outdoor entrance		The indoor entrance	
		Mean temperature (℃)	Mean relative humidity (%)	Mean temperature (℃)	Mean relative humidity (%)
2.29	32	31.2	53.9	27.9	65.9
	30	29.4	54.2	27.7	67.3
	28	27.6	62.5	26.8	66.1
3.60	32	31.1	53.4	27.5	65.2
	30	29.3	54.5	27.1	68.3
	28	27.4	66.2	26.5	63.1

Table 2. Winter air ventilator measurement data in Xiamen (outdoor temperature is 16 ℃, requiring different indoor temperature data)

Mean wind velocity (m/s)	Indoor temperature(℃)	Outdoor fresh air entrance		Indoor fresh air entrance	
		Mean temperature (℃)	Mean relative humidity (%)	Mean temperature (℃)	Mean relative humidity (%)
2.29	25	16.1	55.6	22.0	45.9
	22	16.4	56.5	20.6	44.8
	20	16.0	56.3	18.5	49.0
	18	15.9	55.6	17.1	49.3
3.60	25	15.8	56.2	22.7	42.6
	22	16.1	56.5	20.3	44.8
	20	16.3	55.5	18.9	48.5
	18	15.8	55.4	17.3	49.8

In one set of data as example to calculate: Xiamen design indoor temperature is 26 ℃, relative humidity is 60% in summer, and namely, exhaust air temperature is 26 ℃. Taking on table 1 outdoor air import average temperature 31.2 ℃ and indoor air inlet average temperature 27.9 ℃ under the low wind velocity; outdoor air import average temperature 31℃ and indoor air inlet average temperature 26.6 ℃ under the high wind velocity, By the equation (1) ,

Low wind velocity,

$$\eta_t = (t_{wj} - t_{wc}) \div (t_{wj} - t_{nj}) \times 100\% = (31.2 - 27.9) / (31.2 - 26) \times 10 = 63.5\%$$

High wind velocity,

$$\eta_t = (t_{wj} - t_{wc}) \div (t_{wj} - t_{nj}) \times 100\% = (31.0 - 26.6) \div (31.0 - 26) \times 100\% = 88\%$$

Finally, the result of sensible heat efficiency is shown in table 3 and table 4.

Table 3. Heat recovery sensible heat efficiency under the different outdoor temperature when indoor temperature is 26 ℃ in summer

Outdoor temperature （℃）	Apparent efficiency（%）	
	Low wind velocity	High wind velocity
32	63.5	88.0
30	57.5	66.7
28	50.0	60.1

Table 4. Heat recovery sensible heat efficiency under the different indoor temperature when outdoor temperature is 26 ℃ in winter

Outdoor temperature （℃）	Apparent efficiency（%）	
	Low wind velocity	High wind velocity
25	66.3	75.0
22	75.0	71.0
20	63.0	70.0
18	57.0	68.2

The efficiency curves of fresh air ventilator based on the measured date is shown in Figure 3 and Figure 4. The total heat efficiency of data to calculate in some case is negative. This is because outdoor air enthalpy values less than indoor air enthalpy values. In this case, if you still use fresh air ventilator does not achieve the goal of energy saving.

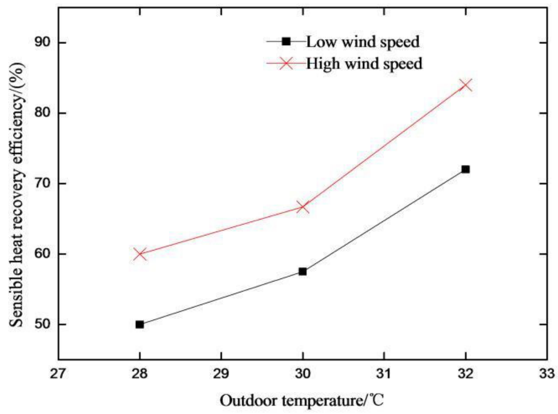

Fig. 3. Heat recovery efficiency under the different outdoor temperature when indoor temperature is 26 ℃ in summer

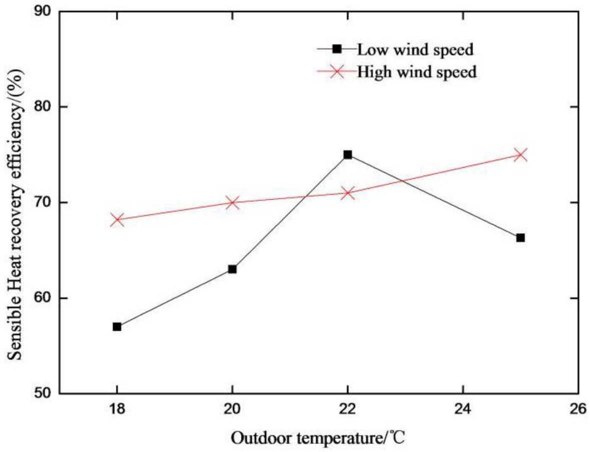

Fig. 4. Heat recovery efficiency under the different outdoor temperature when outdoor temperature is 16 ℃ in winter

If setting indoor air conditioned State N, N point isotherms and isenthalpic line can divide the local outdoor meteorological envelope range into Ⅰ to Ⅳ four meteorological zones, as shown in Figure 5. I zone outdoor air temperature and enthalpy values are lower than the design value of Interior, obviously it’s not suitable for heat recovery; II zone outdoor air temperature is higher than the design value of Interior, enthalpy is lower than the design value of Interior, apparently it’s only suitable for the sensible heat recovery; III zone outdoor air temperature and enthalpy values are higher than the design value of Interior, it is suitable for using as total heat recovery [11].

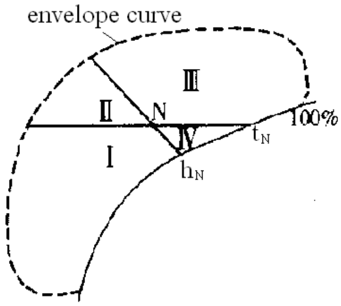

Fig. 5. Meteorological range of heat exchanger air pretreatment system

4. For example energy saving effects analysis

In this paper, we take the summer comprehensive sports center in Xiamen (this project is located in Xiamen; it is usually as the main venue of sports competitions, training and concert. The gym land area is 5700 m^2 and the stadium construction area is about 5700 m^2) as an example to illustrate the energy-saving effect of fresh air ventilator. The stadium Hall uses full air system, and fresh air ventilator is installed in the air-conditioner room. Its interior design parameter of the air conditioning system is shown in the table 5. Using enthalpy wet figure to calculate that the total air volume is 193157 m^3 / h, the fresh air volume is 50640 m^3/ h, the fresh air load $Q_{c.o}$ equals 695.45 KW. The process is shown in Figure 6.

Table 5. Summer indoor and outdoor air computation parameters in Xiamen area

The indoor air condition N		Outdoor air condition W	
dry-bulb temperature	Relative humidity	dry-bulb temperature	Relative humidity
26.0℃	60.0%	33.6℃	81.0%

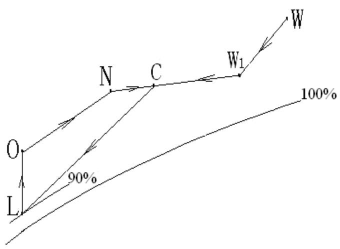

Fig. 6. A return air heat exchanger air pretreatment system process diagram

Because the W point is in the first Ⅲ area, it is suitable for heat recovery. The air, through the heat exchange ventilation, not only has the sensible heat changes but enthalpy changes. Sensible heat exchange efficiency η_t of Fresh air ventilator, which is produced in Xiamen, is 71% and its enthalpy efficiency η_h is 54%. Then parameters of the air through the heat exchange ventilation can be calculated.

$$\eta_t = (t_{wj} - t_{wc}) \div (t_{wj} - t_{nj}) \times 100\% \quad (2)$$

$$\eta_h = (h_{wj} - h_{wc}) \div (h_{wj} - h_{nj}) \times 100\% \quad (3)$$

Where t_{wj} is outdoor air dry-bulb temperature, 33.6 ℃; t_{wc} is send indoor dry-bulb temperature; t_{nj} is Indoor air dry-bulb temperature, 26 ℃; h_{wj} is The enthalpy value before processing; h_{nj} is Indoor air enthalpy;

Substituted into equation (2) and (3): t_{wc}=28.2℃ , h_{wj}= 73.54 kJ/kg.

Cooling capacity required for conventional air conditioning systems are known as Q equals 695.45kW, and the saving energy:

$$\triangle Q = G_w \times (h_{wj} - h_{wc}) \div 3600 = 50640 \times 1.2 \times (87.78 - 73.54) \div 3600 = 240.37\ kW$$

Total heat exchange fresh air ventilator systems combined with air conditioning units can get the energy saving percentage $\Delta\%$, compared with conventional air-conditioning, energy saving effect is obviously considerable.

$$\triangle\% = \triangle Q/Q = 240.37/695.45 = 34.56\%.$$

5. Conclusions

The temperature difference of indoor and outdoor air affects the heat recovery efficiency. The bigger temperature difference is the higher the efficiency. Wind velocity is also a factor affecting the efficiency of heat recovery, in General, high wind velocity higher than low wind velocity in heat recovery efficiency.

Fresh air ventilator is associated with building type and design conditions. A detailed calculation by a stadium in Xiamen shows that fresh air ventilator energy-saving is 240.37kW, which is 34.56% percent of total energy consumption of fresh air with the design-condition in the air-conditioning system in summer. Application of fresh air ventilator in the air- conditioning system not only improves air quality but also reduces building energy consumption. At the same time, the result of testing for energy recovery ventilators and energy saving analysis with air-conditioning systems can provide basic reference data for product improvement and air-conditioning system design.

In the air-conditioning system, increasing fresh air is one of the important means of improving indoor air quality. Health and energy-saving, in the energy-hungry world, are two themes which all air conditioning products have to face today. Fresh air ventilator will not only bring the high quality air into the room but reduce energy consumption. In the long run, application of fresh air ventilator has a broad space for development in China.

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